**Earthquake Hazard in the Pacific Northwest:**
**Rupture Area of Great Earthquakes and Origin of Puget Sound Seismicity**

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## Investigations Undertaken

The grant is to support work on earthquake sources and hazard in the Pacific Northwest. It provides partial support of fellowships and research funding for two graduate students and one postdoctorate fellow. The work is based upon integration of GPS and other geodetic data, tectonic models, seismicity, and coastal studies, to provide: (1) Better constraints on the rupture area of Cascadia great earthquakes (seismic source region), and (2) The region and recurrence times for potentially damaging M~7 forearc crustal earthquakes.

## Results

1. Constraints on the rupture area of Cascadia great earthquakes (seismic source region)

(a) Accurate estimation of the megathrust locked zone and accumulated strain, depends on separating the megathrust deformation signal from the forearc crust deformation (northerly motion). This has been done by removing the predicted horizontal GPS motion at continuous Pacific Northwest sites for the northerly motion of the Cascadia forearc block based upon geological and paleomagnetic data. The resulting deformation vectors are well fit by a 3-D dislocation model for a locked subduction thrust.

(b) the analysis and interpretation of Vancouver Island and northernmost coastal Washington campaign sites has been completed in the PhD thesis of J. Henton (Univ. Victoria). The main conclusions are: (1) The data can be fit to first order by a simple locked

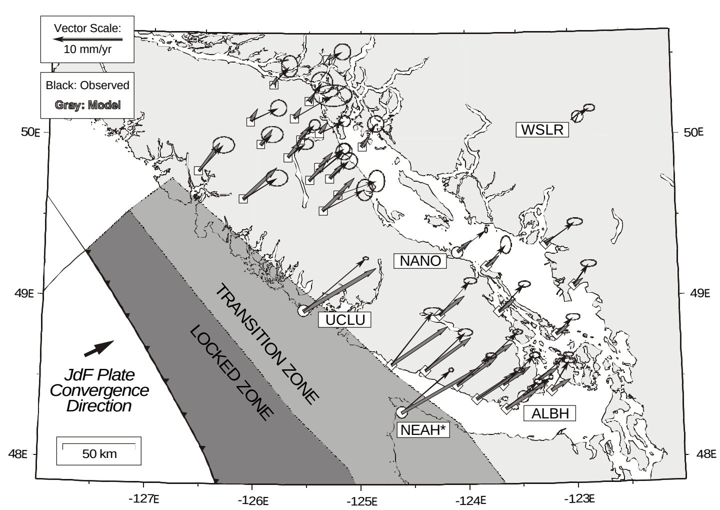


**Figure 1**. Comparison of predicted horizontal deformation of dislocation model with GPS observations (Henton, 2000).

subduction thrust that extends north to the Nootka Fault zone off central Vancouver Island (**Figure 1**). (2) The main misfit is that the observed horizontal vectors at inland sites are somewhat larger than predicted by the simple dislocation models (see below), (3) The data are not adequate to detect whether or not the Explorer plate has a locked subduction thrust beneath north-central Vancouver Island. There is no measurable GPS signal associated with the Nootka Fault zone. (4) There is no deformation signal detected in the area of the two M~7 earthquakes of central Vancouver Island (1918; 1946). Thus, the frequency of such events must be low.

(c) formal inversion of all of the Vancouver Island and northernmost Washington GPS data has been carried out (Yoshioka et al.). This approach has given a locked and transition zone that are very similar to from forward modelling, but that are more rigorously estimated and that gives a slightly better fit to the observed geodetic data.

(d) a revised 3-D dislocation model has been developed for the Cascadia subduction thrust locked zone (Wang et al.). The slip deficit in the transition zone is assumed to decrease exponentially with downdip distance. This model gives a better fit to the magnitudes of GPS horizontal vectors at inner forearc sites than the simple dislocation model. The change in transition zone with time through the earthquake cycle also has been estimated. The coseismic transition zone is estimated to be quite narrow.

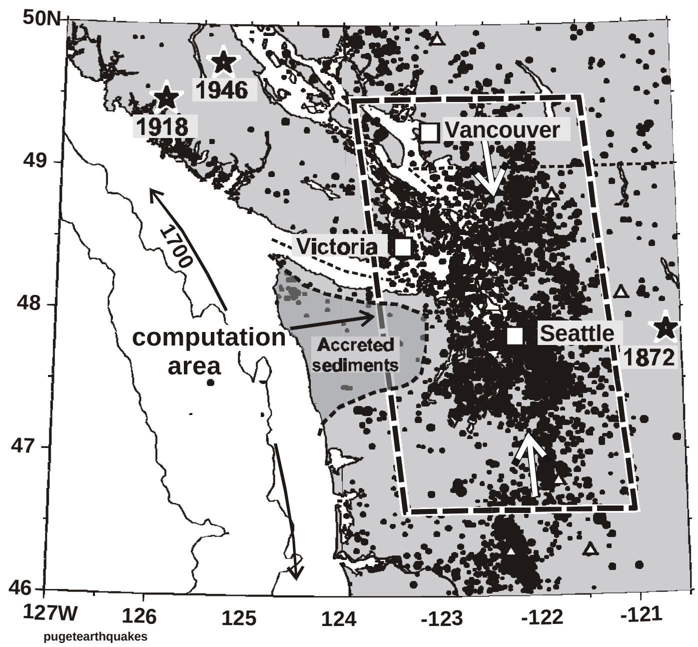


**Figure 2**. Concentration of crustal-only earthquakes in the Seattle-Victoria-Vancouver region due to N-S shortening in the forearc.

2. <u>Forearc motion; areas and recurrence times for M~7 events</u>

In this study we attempt to estimate the recurrence times for large potentially damaging crustal events in the Puget Sound S. Georgia Strait region using GPS data and geological models for forearc northerly motion.

(a) we calculate the seismic moment release rate required to accommodate the estimated north-south shortening rates in the region. In the GPS analysis, we first separate the current deformation signal of the

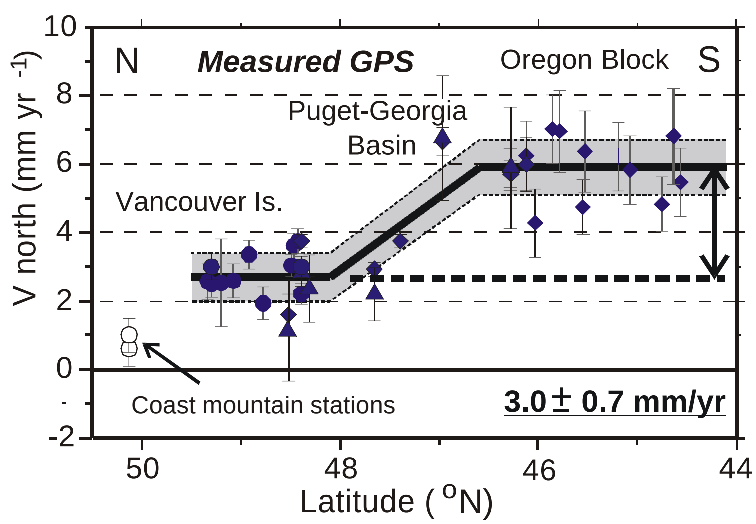


**Figure 3**. N-S shortening of the Puget-Georgia region from GPS data. This rate should correspond to current seismicity.

locked subduction thrust from that of the Cascadia forearc northerly motion, using a model for the subduction thrust. The result is a northerly motion taken up mainly by north-south shortening in the Puget Sound S. Georgia Strait region (Mazzotti et al.) (**Figure 3**). This motion is in agreement with estimates from geological models of forearc motion, if the northerly component of the elastic megathrust cycle is subtracted.

(b) nearly half of the estimated long-term N-S shortening (about 6 mm/yr) is associated with the northerly component of the elastic megathrust cycle. The current interseismic shortening is only about 3 mm/yr. Because of the abrupt component of N-S shortening associated with the megathrust rupture (~1 m), such great earthquakes may be followed by much increased forearc crustal seismicity.

(c) the frequency of occurrence of large forearc crustal earthquakes from the N-S shortening estimates is computed to be M>6 is 0.022/yr (~45 years), and for M>7 is 0.0025/yr (390 years) (Hyndman et al.). This is very similar to the estimates from extrapolating the earthquake catalogue to large magnitudes using the recurrence relation (**Figure 4**). No large "characteristic earthquakes" are required.

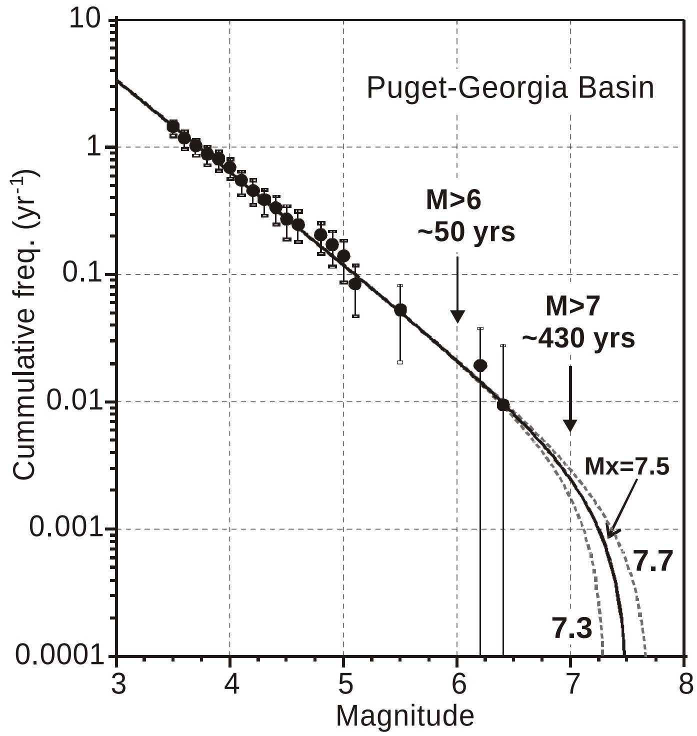


**Figure 4**. Earthquake catalogue statistics for the Seattle-Victoria-Vancouver region. The frequency of large events must be estimated by extrapolation of the rates for smaller earthquakes.

**Non-Technical Project Summary**

This report summarizes some of the results and conclusions of:

(1) a study of the expected rupture area for great subduction zone earthquakes on the Cascadia margin and of the region and frequency of occurrence of large potentially damaging crustal earthquakes in the Tacoma-Seattle-Vancouver, B.C. region. The work includes high precision global positioning GPS and other geodetic measurements and analyses that provide supporting evidence that the rupture area for future great earthquakes will be mainly offshore beneath the continental shelf and slope. Thus the expected shaking, although very large, should not be as severe as if the rupture extended on the megathrust beneath these cities.

(2) Analysis of GPS and geological data that indicates that there is north-south crustal shortening mainly in the Puget Sound region that results in the observed strong shallow seismicity. The large crustal earthquake rate required to accommodate this shortening is estimated to be be, for M>6 a rate of 0.022/yr (~45 years), and for M>7 a rate of 0.0025/yr (390 years). This is very similar to the estimates from extrapolating the earthquake catalogue earthquake rates to large magnitudes.